0.1 μm InP HEMT Devices and MMICs for Cryogenic Low Noise Amplifiers from X-band to W-band

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Introduction

Extremely sensitive receivers with minimum noise performance, high gain, and a high degree of gain stability are required for radiometer applications. InP HEMTs and MMICs are ideal candidates because of their proven low noise and high gain performance [1]. Indeed, InP HEMT-based LNAs operating at cryogenic temperatures are being developed for the radiometer applications, and provide minimum noise temperature performance with extremely high gain and bandwidth at cryogenic operation from X-band to W-band [2-5]. In this paper, we will present the TRW's InP HEMT MMIC technology which has been developed and used for these cryogenic applications. We will present several critical aspects of device design for optimal performance, as well as several examples of state-of-the-art cryogenic LNA performance.

Method and Results

The InP HEMT epitaxial layer structures were grown by molecular beam epitaxy at TRW on 3-inch semi-insulating InP substrates. A schematic of the InP HEMT device is shown in Figure 1, which includes a 65% indium channel that provides slightly higher gain than our baseline 60% indium channel device. The wafers were processed using the baseline TRW InP HEMT MMIC production process [1] which typically shows RF circuit yields of 75% to 80%. The frontside InP HEMT MMIC process provides 750A silicon nitride passivated 0.1 μm T-gate HEMT devices, 100 Ω/sq thin film resistors, 300 pF/mm^2 metal-insulator-metal capacitors, and two levels of metal interconnects. The backside InP HEMT MMIC process provides a 75 μm thick wafer with dry-etched through-substrate vias and backside metal ground plane.

Typical 0.1 μm-gate 65% indium channel HEMT parameters include transconductance of greater than 1000 mS/mm and fT of greater than 200 GHz. The device has been optimized to provide high gain at low drain bias with minimal gate current through heterostructure design and gate recess targeting. Details on device and process optimization, and process yield and statistical variation will be provided at the conference. An example of a coplanar-design, wide bandwidth, 4-stage InP HEMT MMIC for W-band cryogenic applications is shown in Figure 2. A 40 μm periphery InP HEMT is used in each stage of the MMIC. Figure 3 shows the measured cryogenic performance of the MMIC at 20 Kelvin. The MMIC shows about 23 dB gain and a noise temperature of 45 to 60 K (0.6 to 0.8 dB noise figure) over the band of 80-105 GHz. The bias conditions were at a drain voltage of 0.75 V and a total current of 8.1 mA, equivalent to only 6 mW of power. The devices can be biased as low as 0.4V and the MMIC shows only ~1dB lower gain and negligible noise temperature increase, demonstrating the excellent gain at low bias that the InP HEMT devices provide. Figure 4 shows measured and modeled performance of a 3-stage MIC LNA operating from 6 to 12 GHz at 12 Kelvin. It shows a minimum noise temperature of 4K at 8.4 GHz with 36 dB gain. The MIC LNA employs InP HEMT discrete devices with periphery of 200μm. Additional details and examples of cryogenic LNA performance will be provided at the conference to further demonstrate the superior performance of InP HEMT-based LNAs for cryogenic applications.

References

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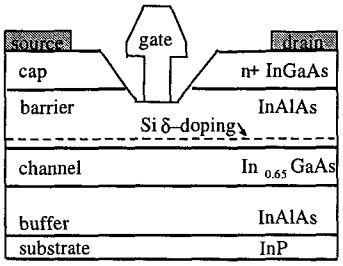

Figure 1. Schematic of the 0.1μm T-gate InP HEMT device.

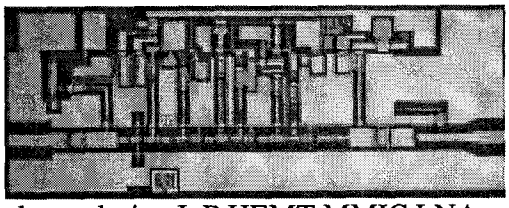

Figure 2. Photo of a 4-stage coplanar-design InP HEMT MMIC LNA whose dimension is 0.8x2.1 mm.

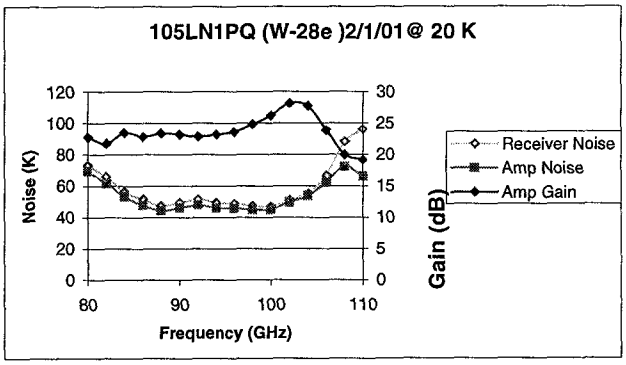

Figure 3. Measured noise termperature and gain performance of the W-band, 4-stage, coplanar-design InP HEMT MMIC LNA measured at 20K at a drain bias of 0.75 V and total current of 8.1 mA.

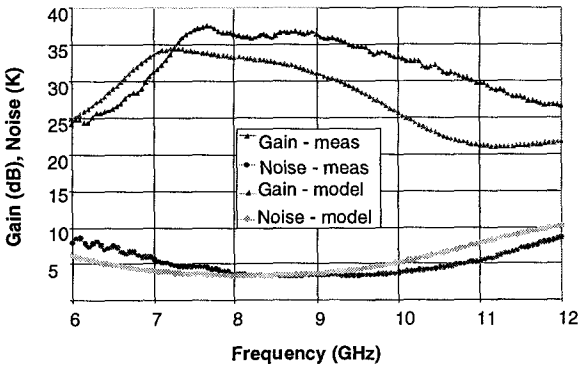

Figure 4. Measured and modeled noise temperature and gain of the X-band, 3-stage, InP HEMT MIC LNA measured at 12K.